Computer Networks

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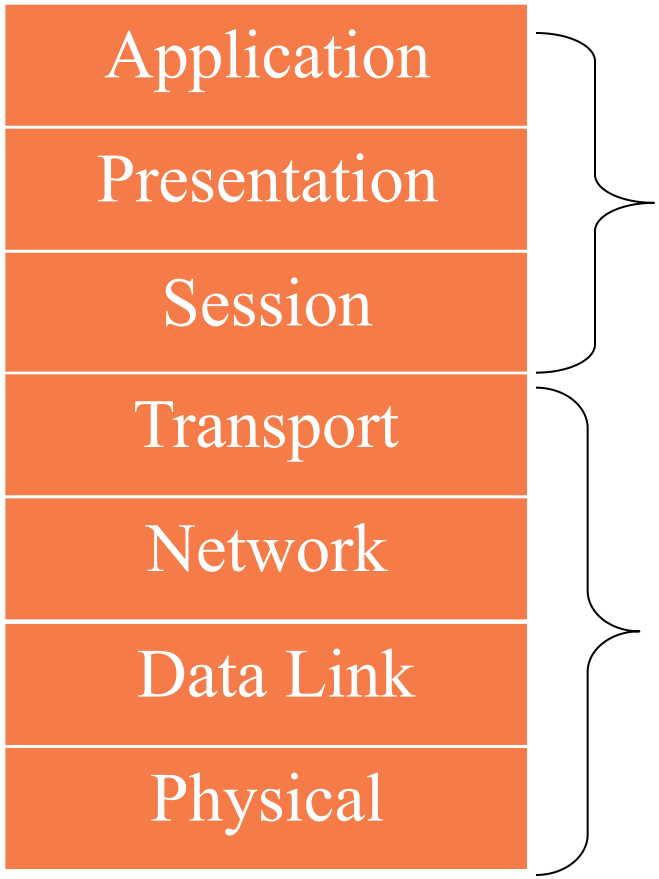
Internet Protocols

OSI Model



APPLICATION
- Upper Layers
- Application oriented
- Independent of layers below

TRANSPORT
- Lower Layers
- Transmission of data
- No differentiation of upper layers

Layer 3

- **Network layer**
  - —Routes the information in the network
  - —Defines addresses in such a way that route selection can be determined.
    - By IP
    - Single address space for the entire internetwork
    - adds an additional layer of addressing, e.g. IP address, which is different from MAC address.

Internet Protocol(IP)

- IP handles end-to-end delivery
- Most commonly used network layer protocol
- All traffic on the internet uses IP

Internet Protocol (IP)

- Upon receiving packet from Transport layer, IP layer generates a header
- Header includes : source and destination IP addresses
- Header is added to front of TCP packet to create a resulting IP packet.
- Purpose of IP is to carry packets end to end across a network.

Addressing

- Addressing level
- Addressing scope
- Addressing mode

Addressing Level

- Unique address for each end system
  - e.g. workstation or server
- And each intermediate system
  - (e.g., router)
- Network-level address
  - IP address or internet address
  - OSI - network service access point (NSAP)
  - Used to route PDU through network
- At destination data must routed to some process
  - Each process assigned an identifier
  - TCP/IP port
  - Service access point (SAP) in OSI

Addressing Scope

- Global address
  - Global nonambiguity
  - Identifies unique system
  - System may have more than one global address
  - Possible at any global address to identify any other global address, in any system, by means of global address of other system
  - Enables internet to route data between any two systems
- Need unique address for each device interface on network
  - Enables network to route data units through network and deliver to intended system
  - Network attachment point address
- Port is unique within system
  - Need not be globally unique
  - E.g port 80 web server listening port in TCP/IP

Addressing Mode

- Usually address refers to single system or port
  - —Individual or unicast address
- Address can refer to more than one entity or port
  - —Multiple simultaneous recipients for data
  - —Broadcast for all entities within domain
  - —Multicast for specific subset of entities

Internetworking Terms (1)

- Communications Network
  - Facility that provides data transfer service
- An internet
  - Collection of communications networks interconnected by bridges and/or routers
- The Internet - note upper case I
  - The global collection of thousands of individual machines and networks
- Intranet
  - Corporate internet operating within the organization
  - Uses Internet (TCP/IP and http)technology to deliver documents and resources

Internetworking Terms (2)

- End System (ES)
  - —Device attached to one of the networks of an internet
  - —Supports end-user applications or services
- Intermediate System (IS)
  - —Device used to connect two networks
  - —Permits communication between end systems attached to different networks

IP Addressing

Purpose of an IP address

- Unique Identification of
  - —Source
    Sometimes used for security or policy-based filtering of data
  - —Destination
    So the networks know where to send the data
- Network Independent Format
  - —IP over anything

Purpose of an IP Address

- Identifies a machine's connection to a network
- Physically moving a machine from one network to another requires changing the IP address
- TCP/IP uses unique 32-bit addresses

Basic Structure of an IP Address

- 32 bit number (4 octet number): (e.g. 133.27.162.125)
- Decimal Representation:

  133 27 162 125

- Binary Representation:

  10000101 00011011 10100010 01111101

- Hexadecimal Representation:

  85 1B A2 7D

IP Address Allocation

- **Private IP address ranges:** A private IP address is a range of non-internet facing IP addresses used in an internal network. This address is only visible within your network, so it is unavailable on the Internet.
  - (10.0.0.0 – 10.255.255.255)
  - (192.168.0.0 – 192.168.255.255)
  - (172.16.0.0 – 172.31.255.255)

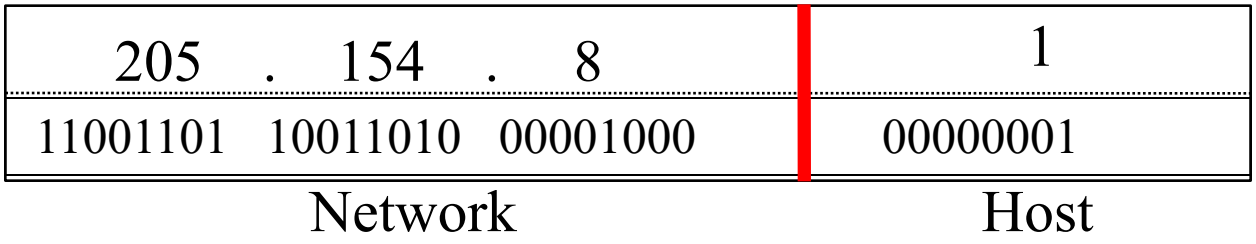
- **Public IP address space:** A public IP address is an address provided that is provided by your internet service provider (ISP) to your network. On the internet, it recognizes your device.
  - Assigned by an appropriate authority such as ISP or Local Internet Registries (LIRs)

Addressing in Internetworks

- The problem we have
  - More than one physical network
  - Different Locations
  - Larger number of computers
- Need structure in IP addresses
  - network part identifies which network in the internetwork (e.g. the Internet)
  - host part identifies host on that network

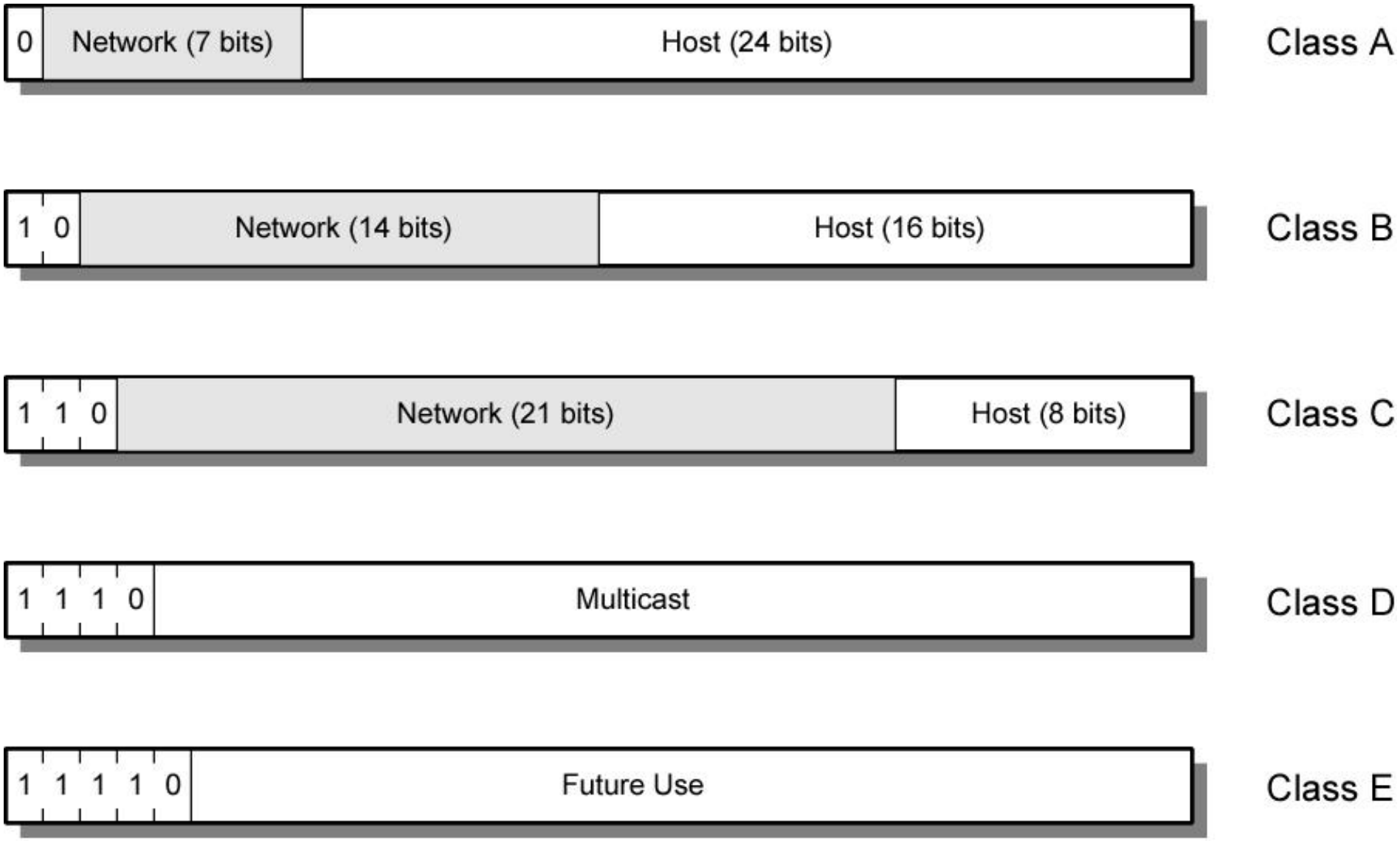
Address Structure Revisited

- Hierarchical Division in IP Address:
  - Network Part (Prefix)
    - describes which physical network
  - Host Part (Host Address)
    - describes which host on that network



  - Boundary can be anywhere
    - very often NOT at a multiple of 8 bits

IPv4 Address Formats



IP Addresses - Class A

- 32 bit global internet address
- Network part and host part
- Class A (Networks with large number of hosts)
  - —Start with binary 0
  - —All 0 reserved
  - —01111111 (127) reserved for loopback
  - —Range 1.x.x.x to 126.x.x.x
  - —All allocated
  - —Number of Networks: 126
  - —Number of Hosts per Network: 16,777,214

IP Addresses - Class B

- Start 10
- For medium to large sized networks
- Range 128.x.x.x to 191.x.x.x
- Second Octet also included in network address
- 2^{14} = 16,384 class B addresses
- All allocated
- Number of Networks: 16,382
- Number of Hosts per Network: 65,534

IP Addresses - Class C

- Start 110
- Range 192.x.x.x to 223.x.x.x
- Second and third octet also part of network address
- 2^{21} = 2,097,152 addresses
- Number of Networks: 2,097,150
- Number of Hosts per Network: 254
- For small local area networks (LANs)
- Nearly all allocated
  - —See IPv6

IP Addresses - Class D

- Range 224.0.0.0 to 239.255.255.255
- Class D IP addresses are not allocated to hosts and are used for multicasting.
- Multicasting allows a single host to send a single stream of data to thousands of hosts across the Internet at the same time.
- It is often used for audio and video streaming, such as IP-based cable TV networks.

IP Addresses - Class E

- Range 240.0.0.0 to 255.255.255.255
- Class E IP addresses are not allocated to hosts and are not available for general use.
- These are reserved for research purposes.

Network Masks

- Network Masks help identify which bits are used to describe the Network Part and which for hosts
- Different Representations:
  - decimal dot notation: 255.255.224.0
  - binary: 11111111 11111111 11100000 00000000
- Binary AND of 32 bit IP address with 32 bit netmask yields network part of address

The Subnet Masks

Class	Decimal notation	Binary notation
A	255.0.0.0	11111111.00000000.00000000.00000000
B	255.255.0.0	11111111. 11111111.00000000.00000000
C	255.255.255.0	11111111. 11111111. 11111111.00000000

00001010.00000000.00000000.00000001 = 10.0.0.1
11111111.00000000.00000000.00000000 = 255.0.0.0

00001010.00000000.00000000.00000000 = 10.0.0.0

Variable Length Subnet Mask (VLSM)

- VLSM allows network administrators to allocate IP addresses more efficiently and effectively
  - smaller subnet masks for subnets with fewer hosts
  - larger subnet masks for subnets with more hosts.
- In a traditional subnetting scheme, a fixed subnet mask lead to inefficient use of IP addresses.
- For example, if a network has two subnets, one with 10 hosts and another with 50 hosts, a traditional subnet mask of 255.255.255.0 would be used for both subnets, which means that each subnet would have 254 available IP addresses. This would result in wasted IP addresses for the smaller subnet.

Variable Length Subnet Mask (VLSM)

- VLSM allows to create subnets with different subnet masks to more effectively utilize IP addresses.
- 255.255.255.128 to the smaller subnet with 10 hosts, which would provide 126 available IP addresses
- 255.255.255.192 to the larger subnet with 50 hosts, which would provide 62 available IP addresses.
- VLSM is widely used in modern networks to create subnets of different sizes and to optimize the use of IP addresses.

Variable Length Subnet Mask (VL

SLASH NOTATION	HOSTS/SUBNETS
/24	254
/25	126
/26	62
/27	30
/28	14
/29	6
/30	2

Classful and Classless Addressing

- Class A, B, C networks require 1, 2 and 3 bytes for the network portion.
- E.g., Class C networks can accommodate only 2^8-2 = 254 hosts (2 are reserved). Small for most medium to large organizations.
- However Class B supports 65,634 hosts – too large. An organization with 2000 hosts ended up with class B addressing – address space was ill used.

Classful and Classless Addressing

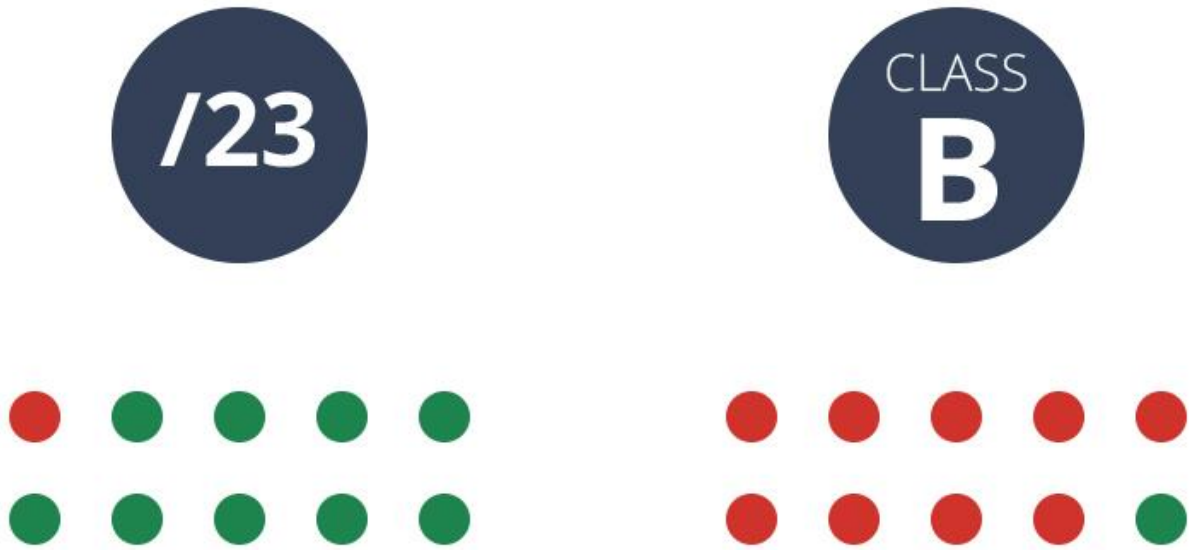
- Classful addressing uses fixed-length subnet masks,
- Classless uses variable length subnet masks.

- **What is classful addressing?**
  - Classful addressing is an IPv4 addressing architecture that divides addresses into five groups.

- ***Limitations of classful IP addressing?***
  - Allocating blocks of 16,777,216, 65,536, or 256 addresses simply wasn't sustainable.
  - E.g. an organization needs 500 IP addresses.
  - Or if it needed just 2 public IP addresses

What is classless addressing?

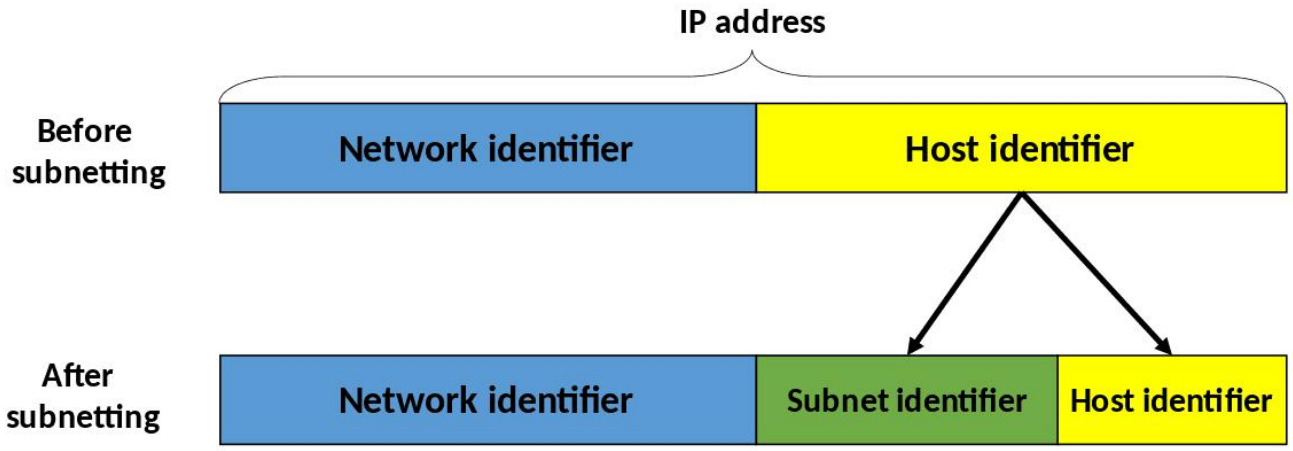
- Classless addressing is an IPv4 addressing architecture that uses variable-length subnet masking.
- *if we need 500 IP addresses*



With a /23, almost all IPs are used. With a Class B, 90% of IPs will be wasted.

Subnetting

- A subnetwork or subnet is a logical subdivision of an IP network.
- The practice of dividing a network into two or more networks is called subnetting.



Subnetting

- Subnetting is the practice of dividing a network into two or more smaller networks.
- It increases routing efficiency, enhances the security of the network, and reduces the size of the broadcast domain.
- All the devices in the same subnet can communicate directly with one another without going through any routers.
- My laptop is on a subnet that also includes a server, a printer, a couple of other workstations, and a router. If I want to communicate with another device in my subnet, I can send packets to it directly. If it's not on my subnet, I need to forward the packet to a router first.

Subnetting

- Any other device with the same network portion is part of my subnet.
- So 192.168.101.1 is part of my subnet and 192.168.101.100 is part of my subnet, but 192.168.102.15 isn’t part of my subnet and I need to go through the router to reach it.

IPV6: Why Change IP?

- Address space exhaustion
  - —Two level addressing (network and host) wastes space
  - —Network addresses used even if not connected to Internet
  - —Growth of networks and the Internet
  - —Extended use of TCP/IP
  - —Single address per host
- Requirements for new types of service
- Explosion of interconnectivity

IPv6 Addresses

- 128 bits long - A 128-bit number supports 2^{128} values, or **340,282,366,920,938,463,463,374,607,431,768,211,456** possible IP addresses. This number is so big there is not even a name for it.
- Preferred IPv6 Addressing Notation
  - 2001:0db8:85a3:0000:0000:8a2e:0370:7D34
  - 2001:0db8:85a3::8a2e:0370:7D34 (compressed form)

IPv6: Advantages

- Larger address space.
- Better header format.
- New options.
- Support for resource allocation.
- Support for more security.